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EVALUATION OF THE KMS 48 FULL FACE MASK CONFIGURED FOR OPEN CIRCUIT UBA WITH CROSSOVER TO EITHER MK 16 MOD 0 UBA OR MK 25 UBA

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EVALUATION OF THE KMS 48 FULL FACE MASK CONFIGURED FOR OPEN CIRCUIT UBA WITH CROSSOVER TO EITHER MK 16 MOD 0 UBA OR MK 25 UBA (UNCLASSIFIED)

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19. ABSTRACT: Testing assessed the abilities of the KMS 48 full face mask (FFM) with closed-circuit/open circuit switchover pod in conjunction with the MK 25 underwater breathing apparatus (UBA) and MK 16 MOD 0 UBA during unmanned and manned open water dives. The KMS 48 FFM with Super Flow scuba pod was also tested during unmanned and manned open-water dives. The dives were made to the maximum operational working depths for each dive rig. Testing revealed that all pieces of equipment performed adequately; they are recommended for fleet use.

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INTRODUCTION

Navy Experimental Diving Unit (NEDU) was tasked to test and evaluate the Kirby Morgan KMS 48 full face mask (FFM) with switchover pod, configured for open circuit underwater breathing apparatus (UBA) with switchover to either the MK 16 MOD 0 UBA or the MK 25 UBA.[1] All testing was performed in accordance with references 2–4.

The KMS 48 FFM (Fig. 1) is a modular unit specifically designed for closed-circuit diving operations. The mask is not a traditional FFM because it lacks an oral nasal cup. It has a seal between the nose and the mouth, and modular pods (Fig. 2) are used in open circuit, closed-circuit, and open/closed-circuit switchover modes for breathing through the mouth only. No current FFM is approved for the MK 25, and the MK 24 FFM is currently approved for the MK 16. Explosive Ordnance Disposal (EOD) has tested and approved the KMS 48 FFM for use with the MK 16 MOD 1; the pod with the switchover block is not part of the configuration. EOD uses the KMS 48 FFM with a soft pod and the current MK 16 barrel valve (Fig. 3). The design of the KMS 48 allows a diver to change breathing sources without having to remove the face mask underwater. Overall, this design will improve diver safety by mitigating the disorientation that cold water causes when divers remove their masks. The reduced size and weight of the KMS 48 offers greater swimming performance and diver comfort than the bulky MK 24 offers. The KMS 48 also is fully compatible with the selected Ocean Technology Systems (OTS) communication system (Fig. 4).

Figure 1. KMS 48 FFM

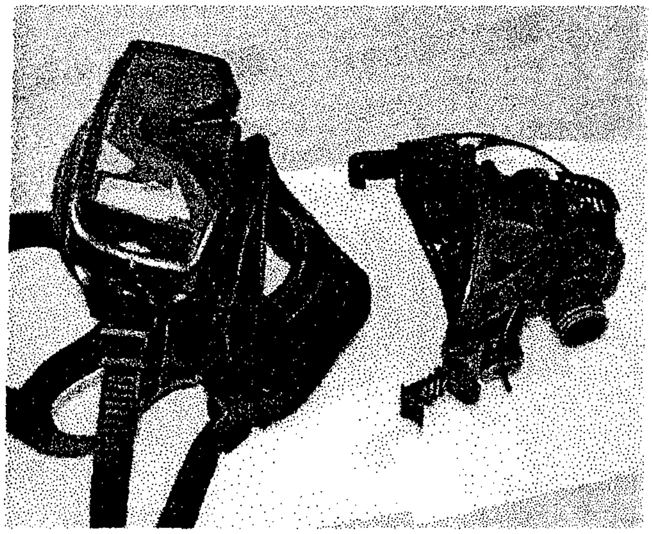

Figure 2. KMS 48 FFM, with switchover pod detached

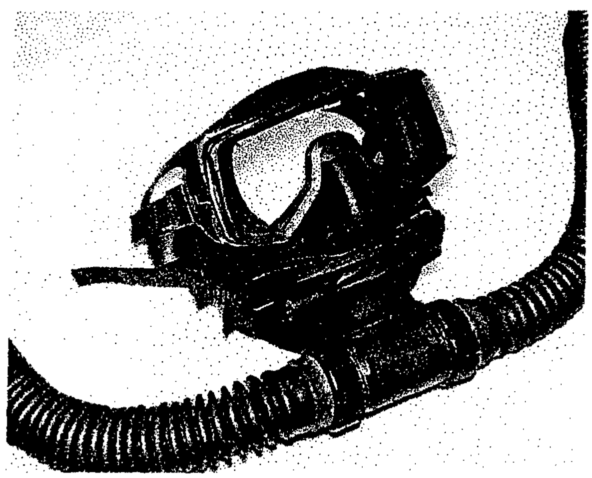

Figure 3. KMS 48 FFM, with soft pod attached to the MK 16 MOD 1 barrel valve

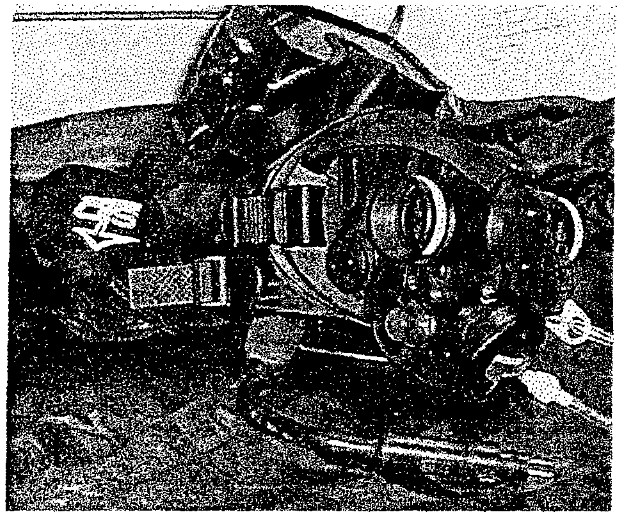

Figure 4. KMS 48 with switchover pod and OTS communications

The benefits of this study include providing SEAL Delivery Vehicle (SDV) operators and combat swimmers with a FFM that integrates open circuit air with a safe switchover to either the MK 16 MOD 0 UBA or the MK 25 UBA. If approved, the KMS 48 will provide a safe means of switching from open to closed circuit and back in training and tactical situations.

METHODS

UNMANNED EVALUATION

GENERAL

Unmanned KMS 48 testing was conducted in the Experimental Diving Facility (EDF). Both open- and closed-circuit breathing resistances were tested, with the test mannequin in the vertical position with the T-bit attached and unattached. All tests in this evaluation followed the methods specified in NEDU Technical Manual 01-94.[5] Since the volume of the rebreather/switchover pod is 290–300 mL, less than the typical FFM external dead space volume of 400–500 mL,[6] no CO_2 washout test was required. The KMS 48 open circuit pod (soft pod with second stage attached), which contains a volume greater than that of the rebreather pod, had already been tested by NEDU and had passed the CO_2 washout test.[7]

The KMS 48 with open/closed-circuit switchover pod was tested in the following configurations:

- Open Circuit Mode — Phases 1 and 2, which do not require attachment to a UBA but do require intermediate pressures of 145 ± 5 pounds per square inch (psi) going into the second stage of the pod.
- Closed-circuit diving with the MK 16 MOD 0 UBA and MK 25 UBA — Phase 3, work of breathing testing.

PROCEDURES

A minimum of one technician was certified formally as a factory-trained technician to ensure correct repairs and tuning of regulators for testing/diving. Because of cost constraints, this technician trained other EDF personnel in proper methods of repairing and tuning regulators. Technical representatives were allowed to visit NEDU to train personnel in using and maintaining candidate regulators they manufacture.

PHASE I — Visual Inspection and Dry Bench Testing

EXPERIMENTAL DESIGN AND ANALYSIS

(a) Testing supply pressures: 3,000 ± 200 pounds per square inch, gauge (psig), 1500 psig, 500 psig
(b) Volumetric flow: 0–30 actual cubic feet per minute (acfm), in 2.5 acfm increments
(c) Test depth: surface
(d) Breathing/testing medium: diver's quality air

EQUIPMENT AND INSTRUMENTATION

Dry bench testing was conducted in the EDF. Unmanned in-water testing was conducted in the EDF unmanned test chamber.

Test setup was in accordance with Regulator Test Bench (NEDU EDF-OP-19).

The following equipment was used:

(a) 3 FFMs with switchover pods

(b) Conshelf XIV first-stage regulator assembly with a quick-disconnect hose assembly

(c) Kirby Morgan Super Flow scuba pod (second stage)

PROCEDURES

Before the candidate regulator was installed on the test stand, it was visually inspected and its general condition and design features were noted.

RESULTS

The overbottom pressure setting results and volumetric flow tests were performed, per manufacturer specifications.

PHASE II — Open Circuit Testing for Resistive Effort in Water Temperatures of 38 ± 2 °F

EXPERIMENTAL DESIGN AND ANALYSIS

(a) Testing supply pressures: 1,500 psig for the downward excursion, reduced to 500 psig for the upward excursion

(b) Test depths: 33, 66, 99, 132, 165, and 198 feet of seawater (fsw)

(c) Breathing/testing medium: diver's quality air

(d) Breathing rates: respiratory minute volumes (RMVs) of 22.5, 40.0, 62.5, 75.0, and 90 L/min

(e) Ark water temperature: 38 ± 2 °F

EQUIPMENT AND INSTRUMENTATION

The following equipment was used:

(a) 3 FFMs with switchover pods

(b) Conshelf XIV first-stage regulator assembly with a quick-disconnect hose assembly

(c) Kirby Morgan Super Flow scuba pod (second stage)

Test setup was in accordance with reference 5, with the following modifications:

(a) Breathing simulator: Reimers Consultants, Model No. BM2B

(b) Keller PSI transducer: Model 289-540-000

(c) Temperature probes for monitoring water and exhaled gas temperatures: Yellow Springs Instruments (Yellow Springs, OH), Series 700

(d) EDF chamber data acquisition computer system, using Microsoft NT Workstation computer system with National Instruments (Austin, TX) data acquisition system and NEDU-developed software, for processing resistive efforts

(e) Bubble diffuser mat

(f) Mannequin torso, mounted upright

PROCEDURES

This phase of testing was conducted in two parts. Resistive effort was determined by analyzing P-V loops in 33-fsw increments from the surface to 198 fsw at 1,500 ± 25-psig supply pressure, then back to the surface at 500 ± 25-psig supply pressure in 33 fsw increments. After data acquisition at 198 fsw was completed, data was collected at each specified RMV (Table 1).

Table 1. Breathing Machine Settings

RMV (L/min)	Tidal volume (L)	Breaths/min
22.5	1.5	15
40.0	2.0	20
62.5	2.5	25
75.0	2.5	30
90.0	3.0	30

RESULTS

The primary first-stage regulator was a Conshelf XIV regulator. Connections to the second-stage regulator consisted of an extended length hose, a quick disconnect, and then another extended length hose. This second-stage regulator was either the black Kirby Morgan miniature regulator attached to the switchover pod, or a Kirby Morgan Super Flow regulator.

With the Conshelf XIV primary regulator, two long hoses, and a quick disconnect, the KMS 48 mask with the miniature regulator met NEDU's performance goals in diving to 33 fsw or shallower. The Super Flow regulator improved the resistive effort enough to increase the diving depth to 66 fsw.

Kirby Morgan Regulator on Switchover Block

Mouthpiece in the mouth: For both 500 and 1500 psi, the resistive effort was below NEDU's performance goal at a ventilation of 22.5 L/min (Figures 5 and 6). However, NEDU's goal was exceeded at depths greater than 165 fsw for a ventilation of 40 L/min. At a ventilation of 62.5 L/min the goal was exceeded for depths greater than 33 fsw.

Mouthpiece to the side: For both 500 and 1500 psi, the resistive effort was below NEDU's performance goal at a ventilation of 22.5 L/min (Figures 7 and 8). However, NEDU's goal was exceeded at depths greater than 132 fsw for a ventilation of 40 L/min with a 1500-psi supply pressure. With a 500-psi supply pressure and a ventilation rate of 40 L/min, NEDU's resistive effort performance goal was exceeded at 132 fsw. At a ventilation rate of 62.5 L/min, the goal was exceeded for depths greater than 33 fsw for both supply pressures.

At greater depths some data points are missing from the figures because the average pressure was too high to be measured.

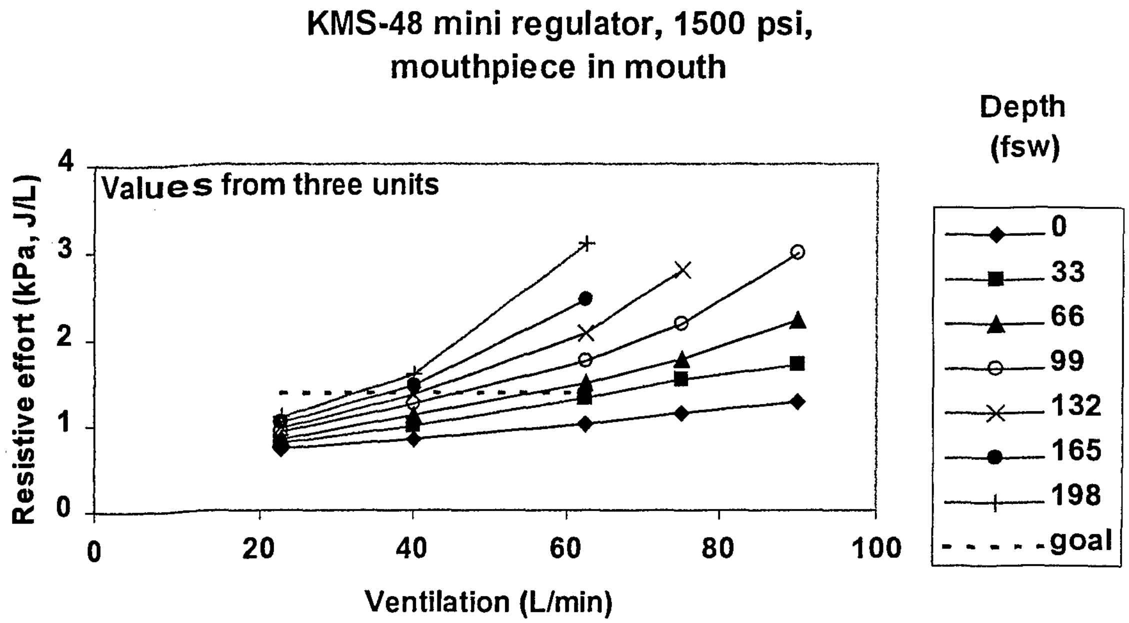

Figure 5. Resistive effort for the KMS 48 with the miniature regulator. Breathing was through the mouthpiece. The supply pressure was 1500 psi. The data shown are averages of 3 masks. At the greater depths some data points are missing because the average pressure was above 4 kPa.

KMS-48, mini regulator, 500 psi, mouthpiece in mouth

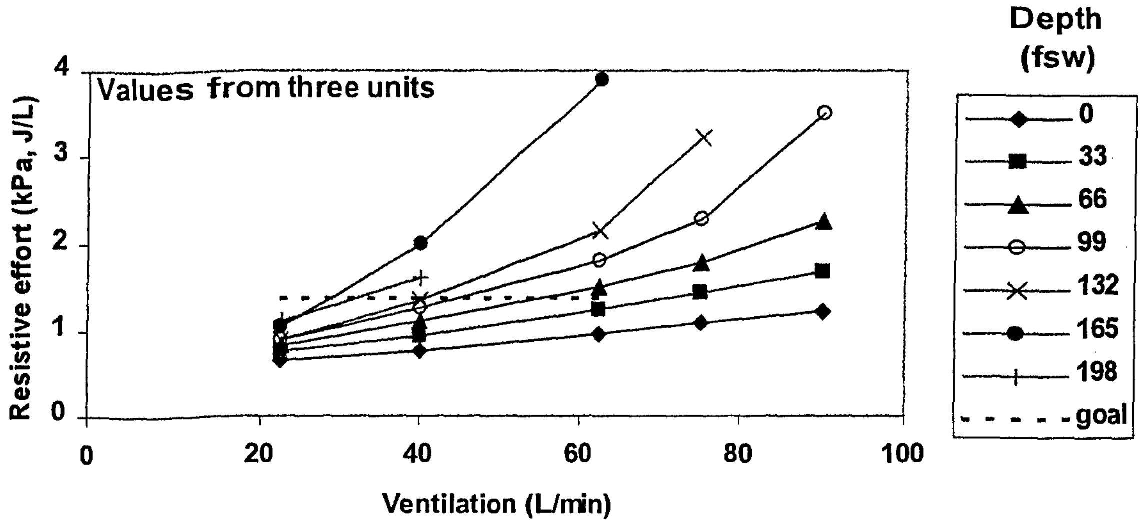

Figure 6. Resistive effort for the KMS 48 with the miniature regulator. Breathing was through the mouthpiece. The supply pressure was 500 psi. The data shown are averages of 3 masks. At the greater depths some data points are missing because the average pressure was above 4 kPa.

KMS-48, mini regulator, 1500 psi, mouthpiece to the side

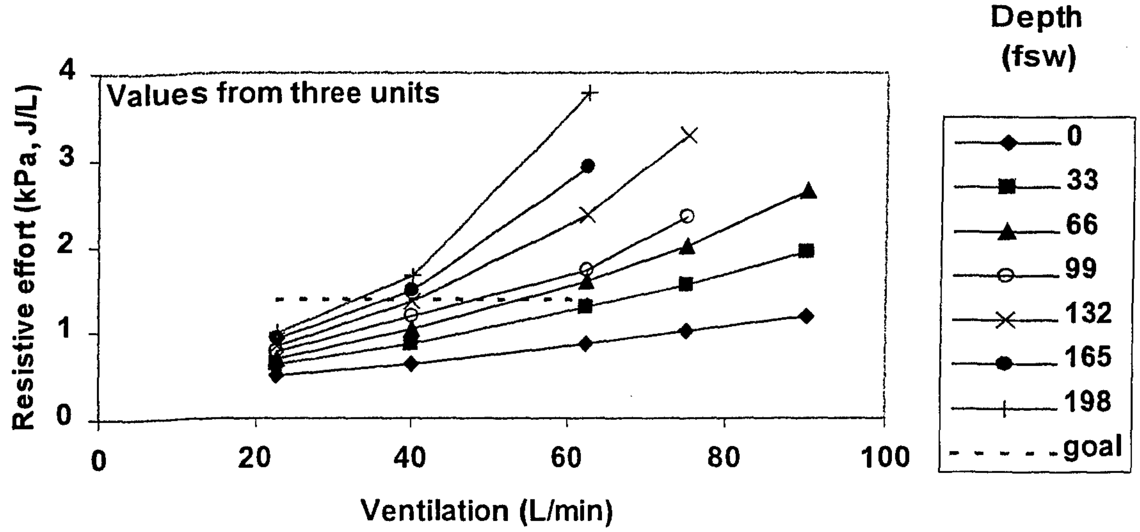

Figure 7. Resistive effort for the KMS 48 with the miniature regulator. Breathing was done with the mouthpiece pushed to the side. The supply pressure was 1500 psi. The data shown are averages of 3 masks.

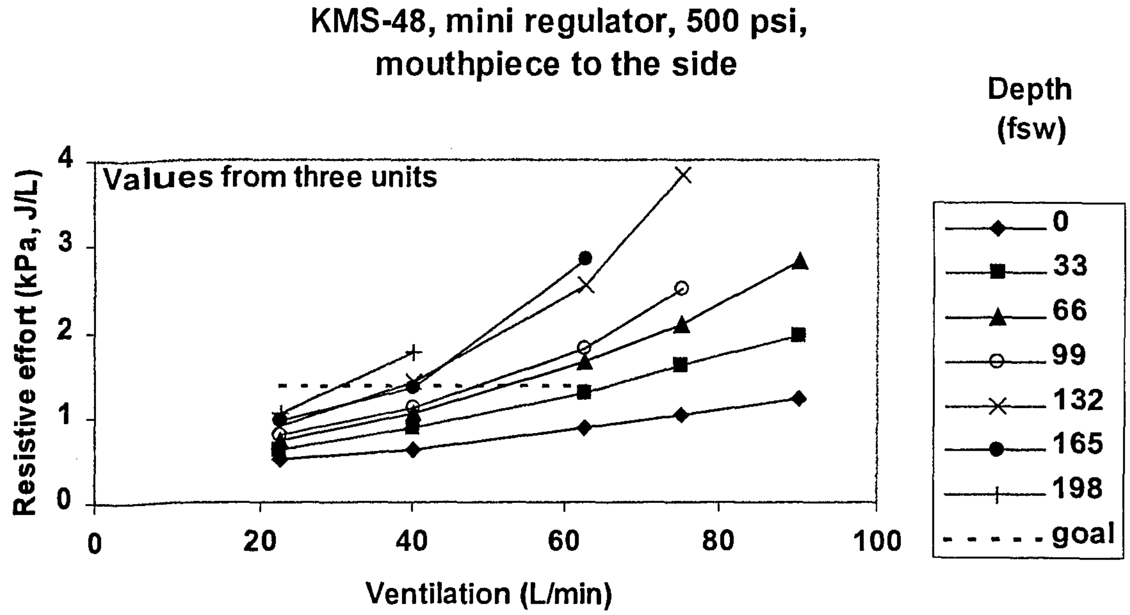

Figure 8. Resistive effort for the KMS 48 with the miniature regulator. Breathing was done with the mouthpiece pushed to the side. The supply pressure was 500 psi. The data shown are averages of 3 masks.

Kirby Morgan Super Flow Regulator

Mouthpiece in the mouth: For both 500 and 1500 psi the resistive effort was below NEDU's performance goal at ventilations of 22.5 and 40 L/min (Figures 9 and 10). However, NEDU's goal was exceeded at depths greater than 66 fsw, with a ventilation of 62.5 L/min.

Mouthpiece to the side: For both 500 and 1500 psi the resistive effort was below NEDU's performance goal at a ventilation of 22.5 L/min (Figures 11 and 12). However, NEDU's goal was exceeded at depths greater than 165 fsw, with a ventilation of 40 L/min. At a ventilation of 62.5 L/min the goal was exceeded for depths greater than 66 fsw.

At the greater depths, some data points are missing because the average pressure was too high to be measured.

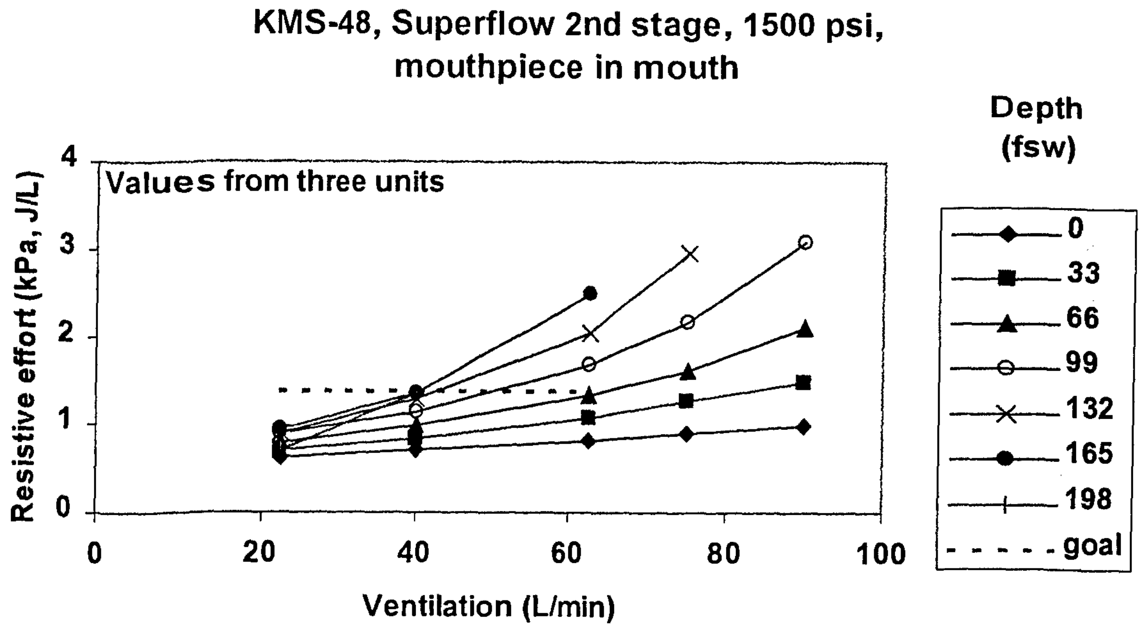

Figure 9. Resistive effort for the KMS 48 with the Superflow regulator. Breathing was through the mouthpiece. The supply pressure was 1500 psi. The data shown are averages of 3 masks.

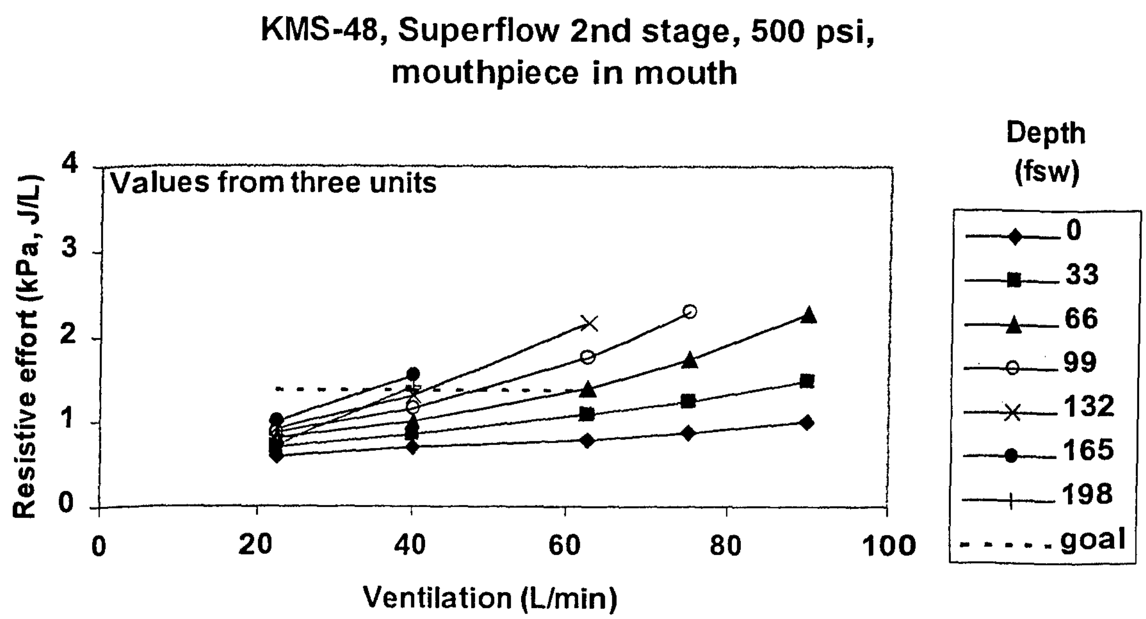

Figure 10. Average pressure for the KMS 48 with the Superflow regulator. Breathing was through the mouthpiece. The supply pressure was 500 psi. The data shown are averages of 3 masks.

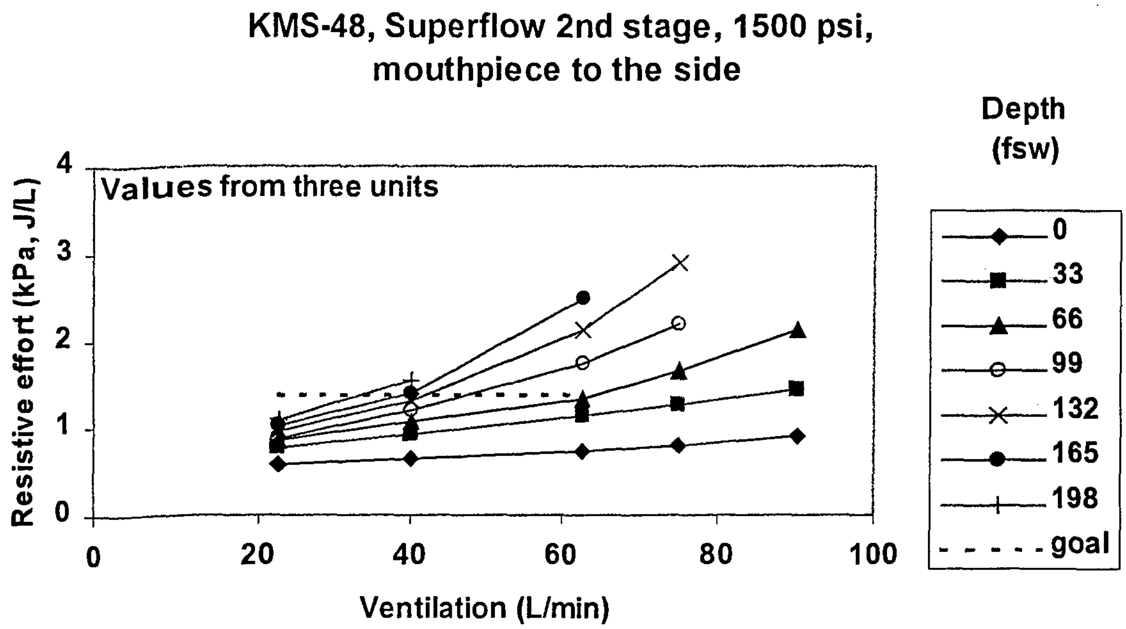

Figure 11. Resistive effort for the KMS 48 with the Superflow regulator. Breathing was done with the mouthpiece pushed to the side. The supply pressure was 1500 psi. The data shown are averages of 3 masks.

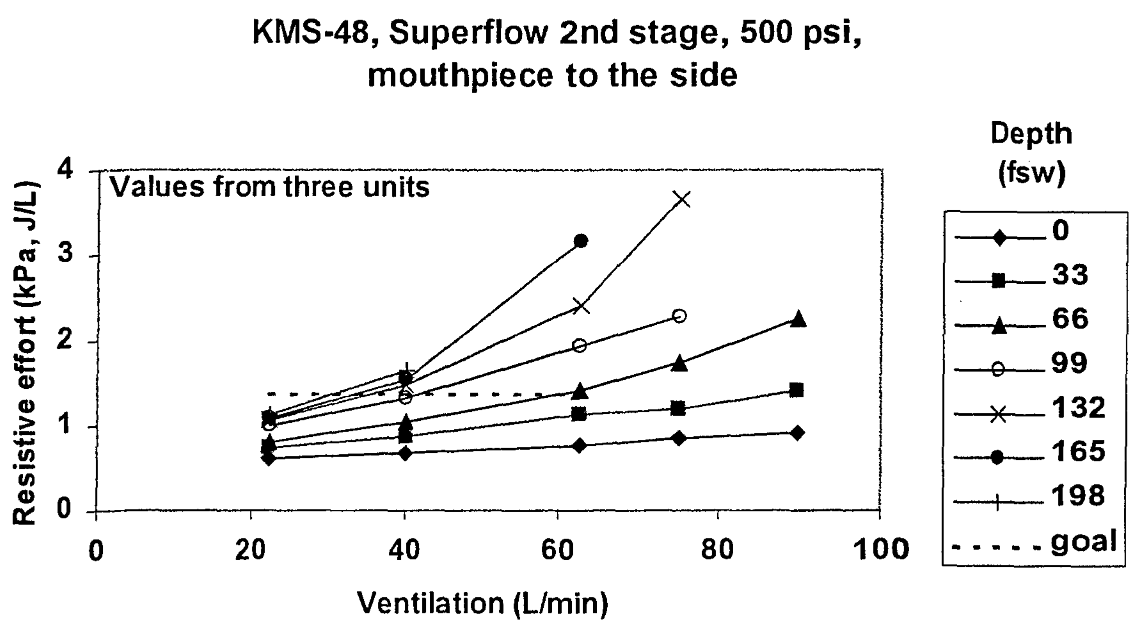

Figure 12. Resistive effort for the KMS 48 with the Superflow regulator. Breathing was done with the mouthpiece pushed to the side. The supply pressure was 500 psi. The data shown are averages of 3 masks.

PHASE III — Closed Circuit Peak Inhalation and Exhalation Breathing Pressures and Resistive Breathing Effort

EXPERIMENTAL DESIGN AND ANALYSIS

(a) Test depths:
- MK 16: 20, 60, and 150 fsw
- MK 25: 20 and 50 fsw

(b) Breathing/testing media — gas supply via UBA's installed gas cylinders:
- For MK 16: diluent and O_2 mix, set point of 0.7
- For MK 25: 100% O_2

(c) CO_2 absorbent: Sofnolime 812

(d) Breathing rates: RMV of 22.5, 40.0, 62.5, 75.0, and 90.0 L/min

EQUIPMENT AND INSTRUMENTATION

The following equipment was used:

(a) 3 FFMs with switchover pods

(b) Conshelf XIV first-stage regulator assembly with a quick-disconnect hose assembly

(c) 1 MK 16 MOD 0 and 1 MK 25 UBAs

Test setup was in accordance with reference 5, with the following modifications:

(a) Breathing simulator: Reimers Consultants, Model No. BM2B

(b) Keller PSI transducer: Model 289-540-0001

(c) Temperature probes for monitoring water: Yellow Springs Instruments (Yellow Springs, OH), Series 700

(d) EDF chamber data acquisition computer system using Microsoft NT Workstation computer system with National Instruments (Austin, TX) data acquisition system and NEDU-developed software, for processing resistive efforts

(e) Mannequin torso, mounted upright

PROCEDURES

This phase of testing was conducted in two parts. Resistive effort was determined by analyzing P-V loops at each depth:

- MK 25: 20 and 50 fsw
- MK 16: 20, 60, and 150 fsw

Before and at the end of every test day we performed required calibrations on the instrumentation to ensure that the collected data were accurate and that data acquisition systems were remaining within acceptable limits.

RESULTS

The KMS-48 does not aggravate MK 25 work of breathing (Figure 13). At lower ventilation rates with the KMS-48 the resistive efforts were comparable to the original MK-16 resistive effort data (Figures 14-16). At higher ventilation rates, however, the resistive efforts with the KMS-48 were greater than the original MK-16 resistive effort data. Furthermore, at 150 FSW, the resistive efforts with the KMS-48 were almost double at the highest ventilation rates (Figure 16). Therefore, when diving the KMS-48 to 150 FSW with the MK-16 UBA, higher resistive efforts should be a consideration.

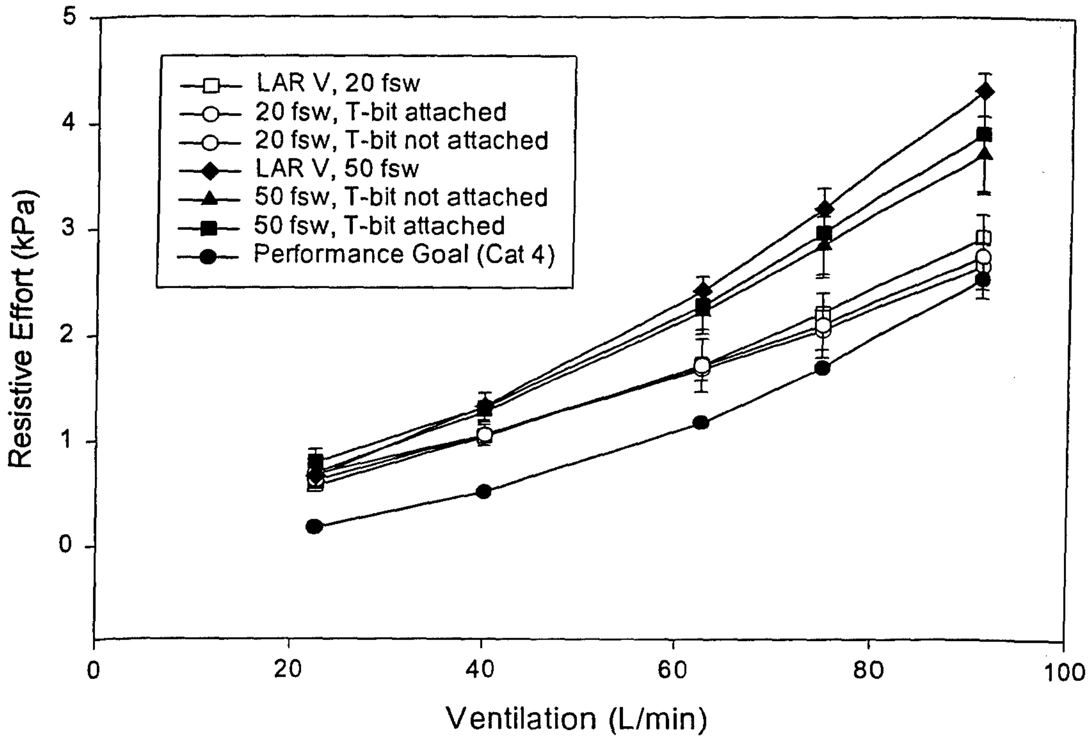

Figure 13. MK 25 work of breathing at 20 and 50 fsw

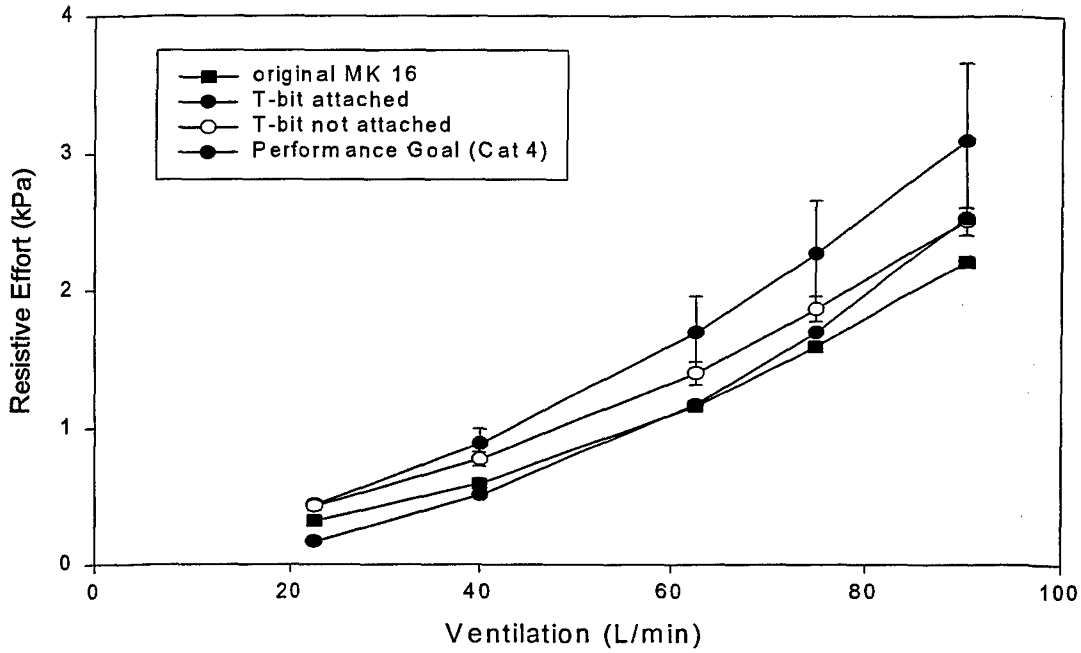

Figure 14. MK 16 work of breathing, 20 fsw

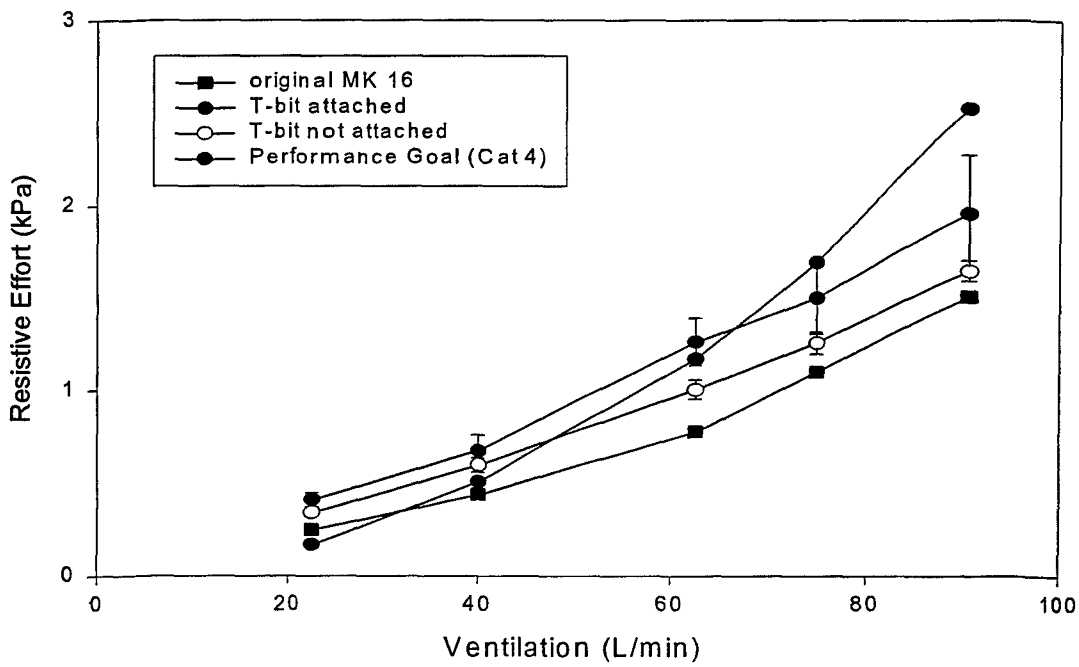

Figure 15. MK 16 work of breathing, 60 fsw

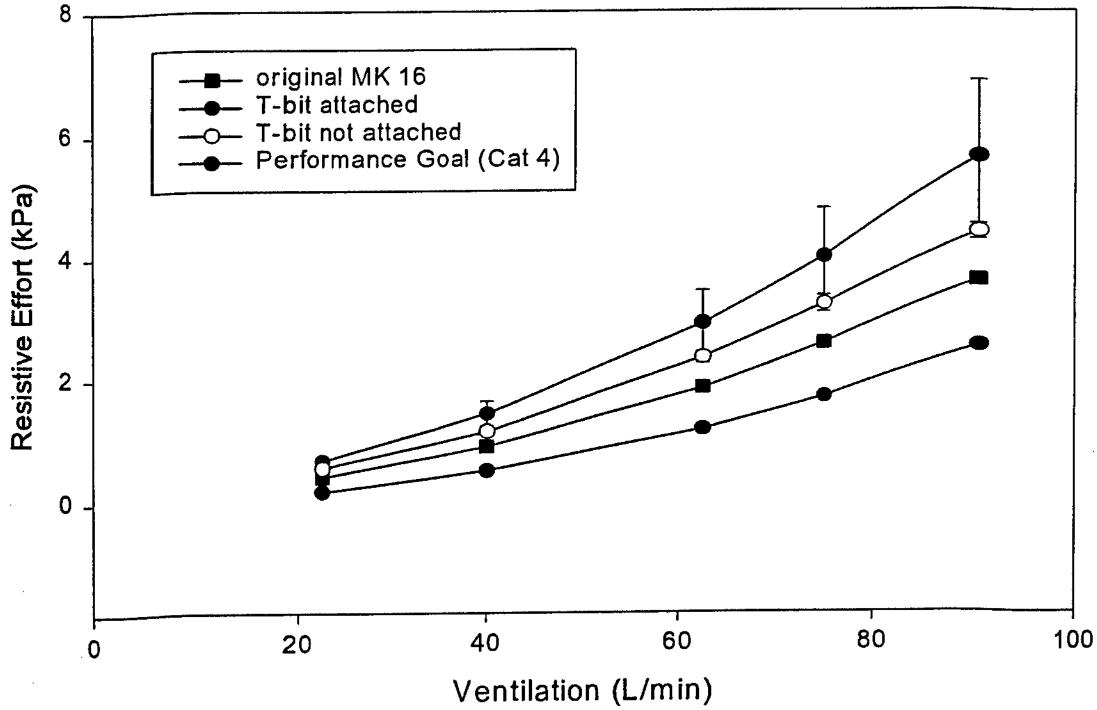

Figure 16. MK 16 work of breathing, 150 fsw

METHODS

MANNED EVALUATION

GENERAL

Manned testing was conducted in three phases. Phase I investigated manned form, fit, and function (FFF) in NEDU's test pool. Phase II encompassed manned dives in NEDU's OSF. Phase III entailed open-water evaluation of the KMS 48 FFM. Operator evaluation of the KMS 48 FFM was recorded via a postdive questionnaire (Annex A).

PHASE I — Form, Fit, and Function

Form, fit, and function tests were performed in the NEDU test pool to familiarize the diver with the KMS 48.

EQUIPMENT AND INSTRUMENTATION

The following personnel and logistic support were required:

Test pool
Qualified dive supervisor
Qualified safety diver
Qualified divers
4 KMS 48 FFMs with rebreather pods and regulators
2 MK 16 MOD 0 UBAs
2 Draeger MK 25 UBAs
2 KMS 48 FFMs with open circuit pods
Topside safety and support gear

PROCEDURES

Dives were conducted in the NEDU test pool with the MK 16 MOD 0 and MK 25 UBAs. Following the deployment of the safety diver and the clearing of divers by the diving supervisor, the divers donned rigs and familiarized themselves with the KMS 48 FFM pod removal and donning. They then proceeded to the stage and practiced pod removal and donning. When they were comfortable with the equipment, they descended to the bottom of the test pool where they were instructed to flood and clear their masks. After clearing the masks, divers resumed normal diving operations. Mask flooding and clearing were performed at least three times, at the discretion of the diving supervisor. The divers were also instructed to remove and don the pod, and to perform typical operations including open- to closed-circuit switchovers and back, to determine

the suitability of the FFM for Naval Special Warfare (NSW) and SDV operations. When switching from open circuit to the MK 25, they used purge procedures for the UBA.[8]

PHASE II — OSF Dives

EQUIPMENT AND INSTRUMENTATION

To complete this test, the following personnel and logistic support were required: NEDU's OSF, with high stage in place and manned with a qualified OSF watch team, and 8 qualified MK 16 MOD 0 and MK 25 divers who had successfully participated in Phase I.

PROCEDURES

Three dives were made in the wet pot of the OSF during a two-day period.

Day One

The dive profile consisted of 2 divers wearing the KMS 48 FFM with the open/closed switchover pod with regulator, and 2 divers wearing the KMS 48 FFM with the open circuit pod. Hooked to open circuit for the duration of the dive, all divers used the facility hoses in the trunk for air as they left the surface on a dive to 190 fsw. Upon reaching 190 fsw, the divers doffed and donned the pod to check these procedures at depth. Following air decompression tables, bottom time was kept to 10 minutes.

Day Two

The first dive profile consisted of 2 divers using the MK 16 MOD 0 with N_2O_2 (79/21) outfitted with the KMS 48 FFM and switchover pods and regulators. The divers left the surface on a 150-fsw dive for 10 minutes; no decompression stop was scheduled.

The second profile consisted of 2 divers using the MK 25 with the KMS 48 FFM and switchover pods with regulators. The divers left the surface, made a stop at 20 fsw for 10 minutes, and then proceeded to 50 fsw for 5 minutes. After 5 minutes at 50 fsw, the divers switched over to open circuit air, breathed on open circuit air, switched back to closed circuit for a few breaths, and then switched back to open circuit air and returned to the surface on air tables.

PHASE III — Open-Water Evaluation

EQUIPMENT AND INSTRUMENTATION

A manned full mission profile of the KMS 48 FFM open/closed-circuit pod for SDV and combat swimmer operations was conducted with the following equipment:

(a) 4 KMS 48 FFMs with crossover blocks and OTS NSW communication systems
(b) 2 MK 16 MOD 0 UBAs
(c) 2 MK 25 UBAs
(d) support craft
(e) 1 SDV

PROCEDURES

Initially the divers were transported on boat air in the SDV. After being transported for an hour, they switched from boat air to their respective rigs by using the switchover block on the KMS 48 pod. They performed SEAL profile operations and after completing these, returned on boat air.

MANNED RESULTS

The questionnaire (Annex A) was used to obtain a total of 15 ratings for the KMS 48 FFM, and 9 for the MK 24 FFM. Results from questionnaire ratings of the KMS 48 and the MK 24 face masks are shown in Table 2. The mean (or average) score on the five-point scale (ranging from 1, "very poor," to 5, "very good") and the standard deviation of the scores are shown. The standard deviation, basically an average of the deviations of each score from the mean, indicates the spread of the scores. Therefore, Table 2 indicates that opinions on the MK 24 generally ranged more widely than those on the KMS 48. However, this spread could also result from the much greater experience that the participants had in diving with the MK 24 than with the KMS 48.

Table 2. Mean rating of the KMS 48 and MK 24 face masks (with standard deviation shown in parentheses)

Items	KMS 48	MK 24
1. Ease of donning and doffing the mask?	4.1 (0.7)	3.9 (1.1)
2. Ease of getting the straps over your head with the mask in place?	4.3 (0.7)	3.8 (1.1)
3. Ease of tightening the straps?	4.5 (0.6)	3.8 (1.4)
4. Ease of loosening the straps and doffing the mask?	4.3 (0.9)	3.8 (1.1)
5. Visibility provided by the mask?	3.5 (1.0)	4.3 (0.7)
6. Overall comfort of the mask as it fits your face?	3.9 (0.6)	2.8 (1.0)
7. Ease of preventing gas leaks around the face seal?	3.8 (0.9)	2.9 (1.6)
8. Balance of the mask?	4.0 (0.9)	2.5 (1.1)
Mean score for overall mask comfort	**4.0 (0.6)**	**3.5 (0.9)**
9. Ease of breathing the mask while at rest?	4.4 (0.5)	4.1 (0.9)
10. Ease of breathing the mask at moderate work levels?	4.4 (0.5)	4.0 (0.8)
11. Ease of breathing the mask at heavy work levels?	4.0 (0.7)	3.9 (0.9)
12. Ability of the mask to remain unfogged?	3.9 (1.0)	3.0 (1.2)
13. Accessibility and operation of the nose-clearing device?	3.7 (1.1)	2.3 (1.6)
14. Ease of clearing the mask after it has flooded?	3.9 (1.0)	3.3 (1.3)
15. How would you rate the ease of speaking during underwater communication while wearing the mask?	4.2 (0.8)	4.0 (0.8)
16. Ease of doffing the mouthpiece?	3.7 (1.2)	N/A
17. Ease of donning the mouthpiece?	3.2 (1.1)	N/A
18. Ease of clearing the mouthpiece and oral mask?	3.9 (1.0)	3.3 (1.5)
19. The seal of the mask with the mouthpiece removed?	4.0 (0.9)	N/A
Mean score for use and operations of mask	**3.5 (0.9)**	**3.3 (1.0)**

Table 2 shows that on every item for which a comparison could be made — except for the visibility the mask provides — the KMS 48 FFM was rated more highly than the MK 24 FFM. This finding is reinforced by the participants' comments (Tables 3 and 4).

Table 3. Comments concerned with the KMS 48

Overall, it [the KMS 48] *has a good concept for SDV work. More comfortable than the MK24/MK 20. Purging water was difficult. So was putting on the mouth piece, but with a little practice is* [*sic*, it] *should get easier.*
I think it [the KMS 48] *was very comfortable and easy to understand and use. I think it is a good mask.*
I noticed upon attaining a vertical, upside down position that a very slight amount of water went into the mouthpiece [of the KMS 48].
Mouth piece donning [of the KMS 48] *depends on technique. It is difficult to don mouth piece without using both hands. i.e. shoving pod into mask, however by grasping mouthpiece in one hand and holding mask in other its fairly easy.*
Overall consensus of divers to clear mask was simply by exhaling through nose in upright position while tilting head to right and holding pod purge — other techniques were performed successfully. However, were more difficult to achieve.
I was unable to clear mask/mouthpiece in either open/closed circuit modes. Mouthpiece was very difficult to put back in mouth after removal. Probably used to soft Pod/M -16 EBS configurations.
Great mask — definitely needed time on it to get used to it. With Draeger it was difficult to breath without off-gassing when not using the T-bit. Recommend a little longer T-bit. Also, when using the T-bit, the top of the chin seal pinches the bottom lip. I really like the fast tech quick release, but needs to be in a different spot to prevent headaches — maybe on side, or top of ring. Also, user [*sic*, use] *a more pliable rubber on the strap to prevent headaches. A little more visibility would be nice.*
Restricted vision, but had more head movement than the MK 24.
Visibility issues with peripheral vision needs improvement. Straps in back pinch the neck of divers *Hood needs to be modified in order for mask to seal properly around pod.*

Table 4. Comments about whether the KMS 48 is better than the MK 24

The MK 24 never fit correctly, was hard to clear your ears and was next to impossible to clear under-water.
The KMS 48 *Is a much better mask for closed circuit diving. Less off gassing due to better ability to control gas*
The KMS 48 *is more comfortable.*
The KMS 48 *is better for comfort and versatility. No- for safety (removable pod).*
I think it will end up being personal preference regarding which mask is used. I like it [the KMS 48] *better and the quicker it gets to the teams the better. Anything to complement our diving tools and give SEALs a choice is good. I feel the mask is great. Its flexibility between Draeger, MK 16, and open circuit is an awesome feature.*
The flexibility you have with the KMS 48 mask is much better than the MK 24, although I would have to say the MK 24 has better visibility and I like the open full face mask more than the regular mask of the KMS 48.
The KMS 48 is easier to clean. However, both masks have advantages and disadvantages. The KMS 48 is easier overall to use.
The KMS 48 is a step forward.

To statistically compare the ratings of the two masks, it was necessary to group those items concerned with mask comfort (items 1–8; Table 2) and those concerned with the use and operations of the mask (items 9–19). Simply to statistically compare each item is not valid: grouping items ensures that the assumptions of the statistical test (in this analysis, the paired sample t-test) are addressed. The paired sample t-test was used to compare the mean "overall mask comfort" scores and mean "use and operations of the mask" scores for the KMS 48 and MK 24 face masks. The paired sample t-test was used to assess whether the difference between the ratings of the two masks is large enough to be significant. The analysis showed that the KMS 48 was rated to be significantly more comfortable than the MK 24 ($t = 3.0$, $df = 8$, $p < 0.05$). The difference between the use and operations ratings of the two masks was not significant ($t = 2.0$, $df = 7$, n.s.).

Participants were also asked whether they thought the KMS 48 was better than the MK 24. Of those participants who responded, 64% (7 participants) thought it was better, and 36% (4 participants) did not know. There were not any "no" responses, and 4 participants failed to respond. The explanations the participants provided for their responses are shown in Table 3.

A summary of the results reveals that participant responses to diving with the KMS 48 were positive: the KMS 48 was consistently ranked more positively than the MK 24. The only item in the questionnaire for which the MK 24 was ranked more highly than the KMS 48 was the visibility provided by the mask. Although some comments about

the mouthpiece of the KMS 48 were negative, the participants had limited experience with the mask, and it is likely that with experience users would become familiar with it. Overall, the KMS 48 was very well received, despite the limited amount of training participants had in using the mask.

CONCLUSIONS

During the unmanned and manned testing, the human factors evaluation and the performances of the KMS 48 FFM, KMS scuba pod with Super Flow regulator, and KMS rebreather pod with switchover regulator provided the necessary quantitative and qualitative data for recommending the use of this equipment for SEAL Delivery Vehicle/Combat Swimmer Operations.

RECOMMENDATIONS

NEDU recommends that the KMS 48 FFM with the KMS-48 rebreather pod with or without switchover regulator be added to NAVSEA00CINST 10560 and thereby authorized for Navy use with MK 16 and MK 25 in NSW operations. Use of the KMS-48 with open circuit SCUBA regulators will be the subject of a subsequent study.

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ANNEX A

EVALUATION QUESTIONNAIRE:
KMS 48 FULL FACE MASK and MK 24X COMPARISON QUESTIONNAIRE

Name of Diver:________________________ Date of Dive________________
Actual Depth:________________ Actual Bottom Time:____________________
Brief Description of Dive: ____
____
____
Diver's dress: ____
Is the diver familiar with the MK 24 Face Mask (Yes/No) __________________

The questionnaire consists of a series of questions which are to be answered with a five-point scale ranging from 1 (very poor) to 5 (very good).

CIRCLE THE NUMBER THAT DESCRIBES YOUR OPINION OF THE MK 24 FACE MASK (COMPLETE PRIOR TO DIVE)

USE AN X TO CROSS OUT THE NUMBER THAT DESCRIBES YOUR OPINION OF THE KMS 48 FULL FACE MASK (COMPLETE AFTER DIVE)

Overall mask comfort	Very poor	Poor	Adequate	Good	Very good
Ease of donning and doffing the mask?	1	2	3	4	5
Ease of getting the straps over your head with the mask in place?	1	2	3	4	5
Ease of tightening the straps?	1	2	3	4	5
Ease of loosening the straps and doffing the mask?	1	2	3	4	5
Visibility provided by the mask?	1	2	3	4	5
Overall comfort of the mask as it fits your face?	1	2	3	4	5
Ease of preventing gas leaks around the face seal?	1	2	3	4	5
Balance of the mask?	1	2	3	4	5

Use and operations of the mask	Very poor	Poor	Adequate	Good	Very good
Ease of breathing the mask while at rest?	1	2	3	4	5
Ease of breathing the mask at moderate work levels?	1	2	3	4	5
Ease of breathing the mask at heavy work levels?	1	2	3	4	5
Ability of the mask to remain unfogged?	1	2	3	4	5
Accessibility and operation of the nose-clearing device?	1	2	3	4	5
Ease of clearing the mask after it has flooded?	1	2	3	4	5
How would you rate the ease of speaking during underwater communication while wearing the mask?	N/A	N/A	N/A	N/A	N/A
Ease of doffing the mouthpiece?	1	2	3	4	5
Ease of donning the mouthpiece?	1	2	3	4	5
Ease of clearing the mouthpiece and oral mask ?	1	2	3	4	5
Sufficiency of the seal of the mask with the mouthpiece removed?	1	2	3	4	5
Ease of use of the "Camelback" hydration system?	N/A	N/A	N/A	N/A	N/A

Please provide any additional information or comments about the KMS 48 mask (complete after dive).

Do you think the KMS 48 is better than the MK 24? Answer yes, no, or don't know. Also, please explain this answer (complete after dive).